Measuring T_2 using a T_2 prepared Balanced Turbo Field Echo Sequence

C. L. Hoad[1], E. F. Cox[1], P. A. Gowland[1]

[1]Sir Peter Mansfield Magnetic Resonance Centre, School of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom

Introduction

Knowledge of tissue relaxation parameters helps to optimise image contrast and detect pathological and dynamic changes. High field MRI scanners are now being used and so it is important to characterise these tissue properties at the new field strengths. Imaging using the balanced turbo field echo (bTFE or TrueFISP) produces images of high SNR with minimal distortions in the abdomen particularly at high field strengths. It was previously shown that T_1 could be measured using this sequence with a suitable preparation pulse[1]. T_2 preparation can also be used with TFE sequences[2]; however quantifying T_2 from the data is not trivial as the final magnetisation at the centre of k-space will depend not only on the preparation phase but also on the r.f. pulses of the bTFE acquisition. The aim of this study was to determine whether T_2 could be measured accurately in phantoms and in-vivo using a T_2 weighted preparation-bTFE (T_2-prep-bTFE) acquisition.

Materials and Methods

All imaging was carried out on a 3.0 T Philips Intera Achieva whole body MRI scanner. Phantom experiments used the SENSE-Head 8 coil and in-vivo imaging the SENSE Torso coil. A gel phantom with 4 quadrants of differing T_1 and T_2 was scanned using a T_2-prep-bTFE sequence with a T_2 preparation module (90º-TE/2-180º-TE/2-90º-bTFE), so that the longitudinal magnetization at the start of the bTFE acquisition was T_2 weighted. Generally half Fourier acquisitions were used to increase the sensitivity to the preparation step. Different combinations of TR/TE and number of pulses to the centre of k-space were used as well as different flip angles. These parameters are given in table 1. For all experiments FOV was 256 mm with a 70% reduced FOV in phase encoding direction, slice thickness was 10 mm. Decay curves were generated by using 8 different T_2 preparation times ranging from 50 to 500 ms. BTFE data was fitted using a program which modelled the evolution of the magnetisation after each r.f. pulse used in the sequence and used Powell algorithm[3] to minimise the difference between measured and modelled data. Data was fitted by either (i) fitting for T_2 and M_0 with the correct T_1 used (measured from EPI data), (ii) fitting for T_2 and M_0 with T_1 10% lower than the measured value, (iii) fitting for T_2 and M_0 with T_1 10% greater than measured value, (iv) fitting for T_2, T_1 and M_0. T_1 and T_2 were also measured using Inversion Recovery-EPI and Spin-Echo EPI imaging sequences which have previously been shown to be very accurate and insensitive to pulse errors[4]. In vivo measurements of T_2 in the liver and spleen were made in a single volunteer repeatedly on two separate occasions. The imaging parameters were the same as Expt 1 (Table 1), with a FOV of 400 mm and 8 different TE/2 times used ranging from 10 to 200ms. As T_1 was not know for the in vivo data T_2 was fitted using the Powell algorithm and fitting for T_2, T_1 and M_0. At present, a single measurement took approximately minutes, and however this time could be decreased if the sequence could be coded in a loop.

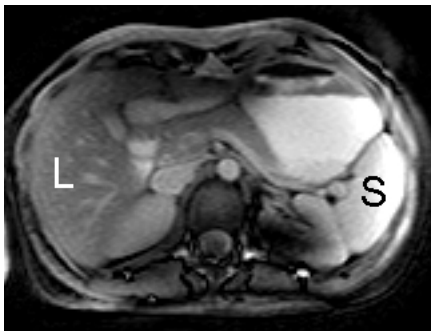

Figure 1. Typical bTFE Image with liver (L) and spleen (S) shown

Imaging Parameter	Expt 1	Expt 2	Expt 3	Expt 4	Expt 5
TR/TE (ms)	3/1.5	5/2.5	5/2.5	5/2.5	3/1.5
Matrix Size	160x256	160x256	160x256	80x128	80x128
No. pulses to centre k-space	23	23	23	45	12
Flip Angle (°)	30	30	50	30	30
Half/Full Fourier	Half	Half	Half	Full	Half

Table 1 – Imaging parameter for phantom bTFE experiments.

	Fitting Type				
ROI	T_2 M_0 (T_1 correct)	T_2 M_0 (T_1 10% under)	T_2 M_0 (T_1 10% over)	T_2 T_1 M_0	EPI
A	0.392±0.002	0.389±0.002	0.395±0.003	0.387±0.007	0.405
B	0.070±0.005	0.071±0.003	0.064±0.005	0.068±0.001	0.071
C	0.068±0.003	0.070±0.001	0.065±0.006	0.070±0.008	0.072
D	0.082±0.002	0.082±0.001	0.081±0.007	0.081±0.002	0.084

Table 2 – T_2 results of phantom experiments in seconds, showing mean±std. dev averaged over the 5 different bTFE experiments for the different fitting algorithms.

Results

Table 2 shows the mean and standard deviation of the measured T_2 data from bTFE expts 1-5 and T_2 measured from the EPI data. Figure 1 shows a typical bTFE image in vivo. Table 3 shows the in vivo data. Expts 1-4 fitted the data better than Expt 5, probably because the image quality was poorest with this data as it had the least number of r.f. pulses.

	Visit 1 (N=5)	Visit 2 (N=3)
Liver	0.035±0.003	0.038±0.001
Spleen	0.063±0.008	0.064±0.005

Table 3 – In vivo T_2 measurements in seconds for a single volunteer scanned multiple times on 2 separate occasions. (mean ± std. dev)

Discussion and Conclusions

All different bTFE experiments gave very similar T_2 results with good reproducibility showing that the sequence can measure T_2 with good accuracy and precision, and showing that the modelling was accurate. The phantom T_2 results were in good agreement with the EPI data, although all T_2-prep-bTFE values were slightly lower. This may have been due to the fitting program using instantaneous r.f. pulses, whereas the experimental data had finite duration r.f. pulses. The preparation sequence is very similar to the spin echo EPI sequence, which we have previously shown is insensitive to RF pulse errors and relatively unaffected by diffusion in the homogeneous field of a whole body scanner. This data suggests that it does not seem to matter whether the fit is 2 parameters or 3 parameters, if the T_1 of the tissue is known quite accurately. In vivo measurements of the liver and spleen were also reproducible and consistent with previously published data using HASTE imaging[5]. The T_2-prep bTFE sequence has an advantage over HASTE as it has a lower SAR.

References 1. Scheffler K, *et al.* Magn. Reson. Med. 45;720-723 (2001), 2 Kaul MG, *et al*. Rofo. 176; 1560-1565 (2004), 3. Press WH, *et al.* Numerical Recipes in C (2nd Ed.); 412, 4. Tyler DJ, *et al.* Magn. Reson. Imag. 22; 1031-1037 (2004), 5. Bazelaire CMJ, et al Radiol. 230; 652-659 (2004).